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Granite outcrops: their utilisation and conservation

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Abstract

Granite, which is exposed over about 15% of the continental areas and is especially prominent in many parts of Western and South Australia, has many attributes which are useful to Humankind. Granite outcrops are useful for quarrying, as catchments in water conservation schemes, as tourist attractions and as recreation areas. Many are of great scientific interest. Granite also has properties which render occurrences hazardous. Granite in contact with water rots easily, slopes tend to be unstable, and blocks of fresh rock are susceptible to displacement by earth tremors. Human interference with slopes introduces and augments problems. Management plans for granite rocks ought to take account of the attributes of particular sites, the merits of competing claims, and possible hazards.

Keywords: granite outcrops, water conservation, quarrying, ecotourism, edutourism, recreation, science

Introduction

Granite is the prime constituent of the continental crust, and though extensively masked by a veneer of volcanic and sedimentary rocks is nevertheless exposed over about 15% of the continental areas. Granite plains and hills are commonplace in the shields and cratons which form the ancient cores or nuclei of the continents. They are also prominent in orogens or fold mountain ranges (*e.g.* Wilhelmy 1958; Godard 1977; Twidale 1982a; Vidal Romani & Twidale 1998; Ikeda 1999; Twidale & Vidal Romani 2001).

In Australia, granite forms extensive outcrops in various of the shields and cratons (*e.g.* the Yilgarn and the Pilbara blocks, in Western Australia, Eyre Peninsula and other parts of the Gawler Craton in South Australia) and is also well represented in mountainous regions such as the Eastern Uplands (Palfreyman 1984). Many well-known uplands and hills like Mt Kosciusko, Mt Buffalo, Wilson's Promontory and Mt Augustus are granitic. Moreover, because it is a hard or resistant rock when dry but is readily altered when in contact with water, fractures in the rock have been weathered by meteoric and ground waters to produce dramatic formations such as some of the Devil's Marbles (Fig 1A). Also, when it is fresh, granite is brittle and cracks easily under stress, again producing spectacular features such as split rocks and A-tents, or pop-ups (Fig 1B). Furthermore, many granite exposures have been intricately sculptured to give cavernous forms such as Remarkable Rocks on Kangaroo Island, and flared slopes such as Wave Rock on Hyden Rock (Fig 1C). Add to these such random erosional forms as the natural coastal arch at Albany, the dramatic wedge and sheet of rock exposed at West Beach, near Esperance, the huge boulder known as The Leviathan, in Victoria, and the sheer simple grandeur of the many granite domes (Fig 1D) that occur in many parts of the country, and it is not surprising that many granite outcrops are tourist and recreational attractions at national and local scales.

Positive attributes

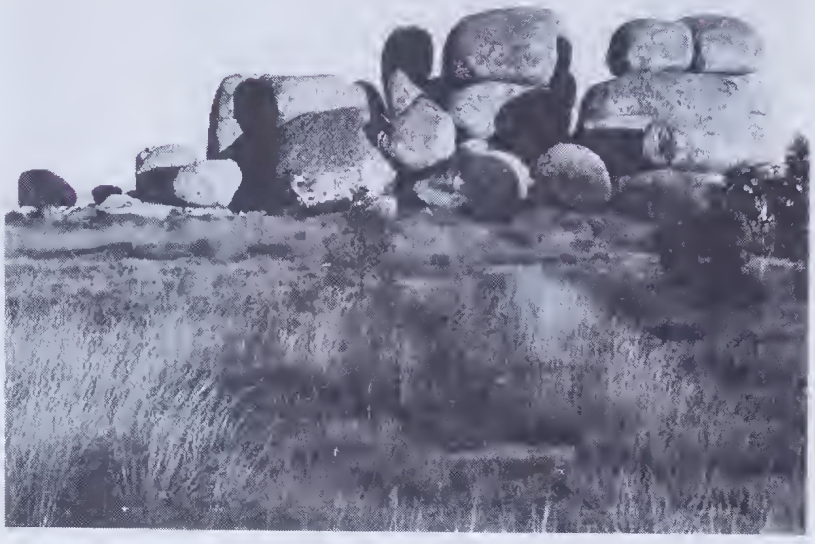
Granite has many other positive attributes and qualities. Though by definition consisting mainly of quartz and feldspar, granites vary in colour and crystal size and many are aesthetically pleasing. When polished, it makes a beautiful stone with hues of rose, pink and mauve, and in some instances, with large crystals (phenocrysts) set in a fine-grained ground mass. Thus many granites have been used for monumental purposes such as the facings of public buildings, paving and headstones. The crushed rock is useful as ballast and gravel. Massive granite is impermeable, so that outcrops make good catchments and storage areas which are especially valued in this, the most arid of the inhabited continents. Moreover, the development of some granite forms, such as flared slopes and stepped bornhardts or inselbergs, has implications for general theories of landscape evolution. Some sites are of scientific interest and importance not only to Earth scientists but also to biologists, for granite hills offer a wide variety of habitats and niches for plants and animals, as well as features attractive to casual visitors.

For these reasons, granite outcrops and landforms are regarded as resources which can be utilised in a variety of ways; they are subject to the competing, and in many instances mutually exclusive, interests of quarrymen, water conservationists, tourist operators (both organised and local), biological conservationists and other scientists, and, justifiably, ordinary folk who cherish local hills as picnic spots and for other recreational purposes.

Potential hazards

On the other hand the specific character of granite weathering and regoliths introduces special and additional risks. Fresh granite is impermeable, but rapidly alters when in contact with water. Thus the mantle of weathered rock (the regolith) characteristically meets the underlying fresh granite in a sharp interface known as the weathering front. The regolith, consisting

A



B

C

D

Figure 1. A: Part of the Devils Marbles, Northern Territory. B: A-tent, or pop-up, on Bald, or Murray, Rock, east of Hyden, Western Australia, Western Australia. C: Alveolar weathering, Remarkable Rocks, Kangaroo Island. D: Mt Lindsay, north-west of South Australia (Geological Survey of South Australia).

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Figure 2. Granite regolith with core-boulders, Snowy Mountains, New South Wales.

of a mix of quartz and clay rests on a surface of fresh rock. Moreover the weathering of granite is frequently incomplete so that the regolith typically consists of boulders (corestones or core-boulders; Scrivenor 1931) and blocks of fresh granite sitting in a matrix of quartz and clay, or just clay (Fig 2). On slopes, and especially steep slopes of course, this is a dangerous situation. Several hazardous situations can be identified.

- First, meteoric waters percolate through the regolith and run along depressions in the impermeable weathering front and form underground streams. Sand and clay fall into the stream from the sides and roofs of such subterranean channels. Eventually the undermined regolith subsides into the channel. The clay-quartz matrix tends to liquify and lose strength. This was the basic cause of the Thredbo (NSW) disaster of July 1997. If there are numerous large blocks and boulders, then the removal of the matrix may cause them to collapse and settle against each other forming irregularly shaped caves, such as have been recorded from Malaysia, Australia, the USA and Guyana; but again there is the potential for inducing settling and surface subsidence. These tendencies are increased if, for any reason such as road construction and drainage works upslope, water is channeled into or on to the regolith.
- Second, following heavy rains or other large accessions of water, or shaking during an earth tremor or earthquake, the entire slope may lose cohesion and fail, carrying downslope large volumes of clay and sand and the contained core-boulders.
- Third, human interference with the regolith such as clearing of trees and/or cutting away the toe of the slope (road construction, land development) causes the regolith to become unsupported or unbuttressed, again leading to failure and the mass movement of debris. Thus, at Paya Terubong on Pulau Penang, West Malaysia, tall apartment blocks (Sun Moon City) were constructed on a granite platform excavated at the base of a high, steep-sided and wooded granite ridge, and a car park was provided by cutting into the base of the slope. On 28 November 1998, a major landslide on the slope above one of the apartment towers carried sand, clay and huge core-boulders (one some 10 m diameter) downslope, burying and crushing a number of parked cars (all fortunately unoccupied) and reaching within about 10 metres of one of the tower blocks. The reason the landslide developed at the time it did (heavy rains, earthquake) is not known, but over the previous two years there were warning signs such as small blocks falling down the slope and the development of what were locally called "waterfalls" (small springs due to water percolating through the regolith, encountering an obstacle such as a core-boulder and emerging under pressure).
- Fourth, the sheet structures typical of many granite outcrops pose further problems, for detached slabs can slip downslope as a result of rains or earth tremors, or where the lower slopes have been undermined or steepened either naturally or by human activities (Fig 3). Thin sheets may buckle either under gravity or as a result of compression associated with earth tremors and 'quakes (Trudinger 1973; Twidale & Sved 1978; Bowling & Woodward 1979; Bourne & Twidale 2000). This can cause dislocation of slopes, with negative implications for quarrying and for dam and pipeline construction. Dipping sets of orthogonal joint systems introduce similar dangers in coastal cliffs, road cuttings, and so on.
- Fifth, frequently the rock in which granite hills are eroded is in compression, with implications for quarrying and other engineering procedures (Vidal Romani & Twidale 1999; Twidale & Bourne 2000a).

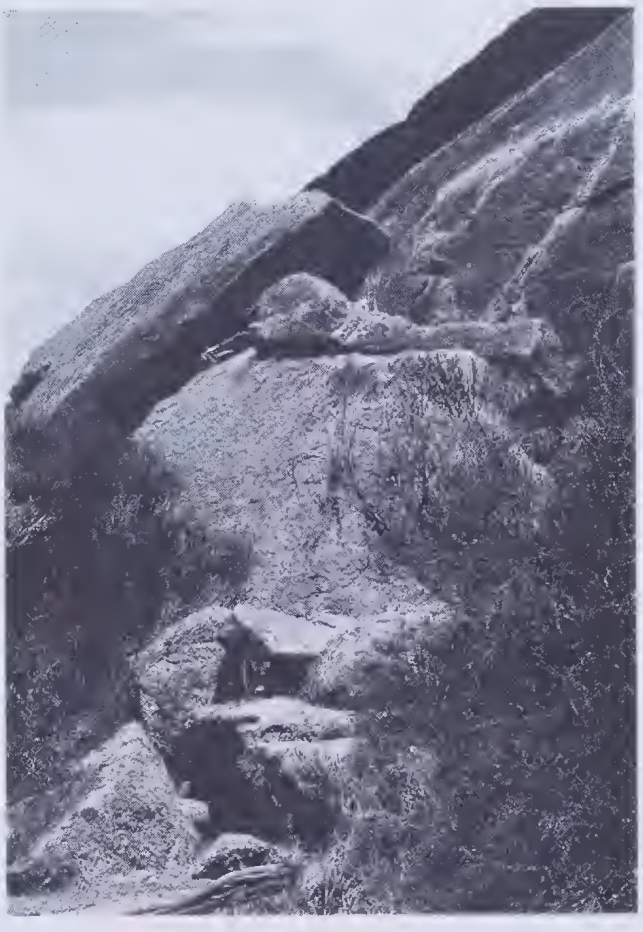

Figure 3. Slipped slab at Kokerbin Hill, Wheatbelt of southwestern Western Australia.

Possible uses of granite outcrops

Quarrying

Quarrying is essential for our lifestyle (gravel for roadbuilding, ballast for railways, building and monumental stone). It generates considerable employment and income. Quarrying is also useful for professional geologists, for it provides clean exposures of rock. Quite understandably in view of the recent and continuing but inevitable rural downturn in employment (inevitable because of various technological advances both general and agricultural) and the stress thus placed on country towns and rural populations, local authorities are, quite properly, examining every new employment possibility; of which quarrying is one.

Unfortunately, quarrying is irreversible. Once gone, the hills quarried cannot be replaced. Moreover, the

clean-up record is unimpressive, and more likely than not the natural feature will in time be replaced by a hole, possibly flooded, with a jumble of blocks and with various constructional and industrial debris scattered around.

The quarry industry is not labour-intensive. Modern procedures, involving drilling, blasting, burning and the use of heavy trucks and cranes, are noisy and dirty. They are unhealthy, not only through accidents, but also through such ailments as silicosis and noise-induced deafness (*e.g.* Noor 1988). The incidence of silicosis in quarry workers can be drastically reduced or eliminated by the introduction and implementation of adequate dust extraction, water sprays to settle dust, compulsory use of respirators, monitoring health checks, and education, but it is difficult to ensure implementation. For example in granite quarries in Selangor, West Malaysia, despite government regulations only 14% of workers regularly used the respirators supplied and 47% never used them at all, for they were considered too uncomfortable to wear in the prevailing heat. Consequently some 4% of workers contracted silicosis (Noor 1988); this is not a high proportion, but in our industrial and legal climate it is potentially expensive as well as personally tragic. More telling, in Selangor 79% of quarry workers suffered noise-induced deafness in some degree. Thus, apart from more obvious and immediate hazards in the shape of rock bursts, falling slabs and accidents with explosives, those encouraging quarrying should be aware of long-term health risks and must not dismiss or fail to disclose them.

The benefits and drawbacks of quarrying in the short, medium and long terms need to be weighed against alternative employment possibilities, and if quarrying is a favoured option then great care needs to be taken in selecting the hills that are to be quarried in light of local, regional, national and international needs, possibilities and motives.

It is questionable whether district or shire councils should be actively involved in promoting, much less having a financial interest in, a quarrying venture. They are responsible for the total well-being of a district, yet if they have power to make decisions concerning a venture in which they have a financial stake, then a conflict of interest situation surely arises? For example, if the council or its officers favour a proposal, full disclosure of aims and implications may not be forthcoming, the precise extent and locations of quarrying may not be fully made known, or the nature and extent of possible health problems may remain unmentioned or understated until a formal and legally binding decision has been taken, simply in order to avoid opposition. Any adverse health effects may not become evident for 25 years or so, when the decision-makers may well have moved on, leaving the community to carry any costs arising from the venture; and similarly to bear clean-up costs. But the major consideration with quarrying is that it is irreversible; once done there is no going back, no time for regrets, no possibility of taking advantage of hindsight.

Water conservation

Water conservation has long been practised in arid and semiarid Australia. Aboriginal people, Afghan camelmen and early shepherds took advantage of the gnammas (or rock basins) characteristic of granite outcrops, cleaned them out and in some instances covered them with a rock slab to save life-giving water. They also built low walls to dam shallow valleys, and created storages where none existed before by constructing inverted roofs draining into tanks. Some of the latter are still in use and are, of course, independent of granite hills or any other uplands.

Whereas the early reservoirs were natural, small and received runoff from limited areas, later users constructed reservoirs to utilise very large catchments based on granite hills and platforms, augmented by diverted runoff (see *e.g.* Twidale & Smith 1971; Laing & Hauck 1997; Fig 4A,B). Some, like those at The Humps, near Hyden, in the Wheatbelt of Western Australia, and many of those on northern Eyre Peninsula, were designed and constructed by government agencies. Many were built during the Depression years of the 'twenties and 'thirties and in response to the needs of stock on the newly opened wheat and sheep country of the southern States. Many are minor works of engineering art (Twidale & Smith 1971). Other water conservation works, like the diversion walls constructed high on Hyden Rock, and especially that located immediately above Wave Rock, are not pleasing to the eye; the needs of the time dictated the area of catchment enclosed and outweighed any aesthetic considerations. In passing it may be noted that the Hyden Dam, as well as the diversion walls, are located between or amidst zones of recent tectonic disturbance (Twidale & Bourne 2000b; see also Kiersch 1964).

Other conservation schemes are privately owned and constructed. Some are elaborate like that at Ucontitchie Hill, north-western Eyre Peninsula, whereas others are simple and involve collecting water from only a few square metres of bare rock surface (Fig 4C). Some serve a district, like that at The Humps which supplies Hyden township. By contrast, in the 'thirties and 'forties, water from the Pildappa Rock tank, north of Minnipa, on north-western Eyre Peninsula (Fig 4B) was piped many kilometres to various neighbouring homesteads and troughs, and that at King Rocks, east of Hyden, serves several adjacent farms. By contrast, many others, like that at Dumonte Rock, near Wudinna, partially meets the needs of a single farm.

The elaborate conservation schemes constructed on north-western Eyre Peninsula in the years 1913-1932 were allowed to fall into disrepair from the early 'sixties through the 'eighties with the completion and renovation of the Tod River Pipeline, but with increasing demand for water for stock some are being brought back into service, mostly through private repair and maintenance.

The diversion of runoff into storages reduces the recharge of groundwaters, and in some areas this can be critical. For example, Streaky Bay, the small farming, fishing and tourist centre on the west coast of Eyre Peninsula, derives its water supply partly from home storage tanks into which roof runoff is drained and partly from the adjacent Robinson Basin. Here, a thin layer of freshwater derived from rainfall floats on denser saline waters (see Segnit & Dridan 1938; Shepherd 1985). Any conservation on granite outcrops would disturb an already delicate situation.

Figure 4. A: The compact surface of Pildappa Rock, near Minnipa, north-western Eyre Peninsula seen here from the south, is about 400 m from west to east and is used as a catchment; a half-million gallon storage tank is seen at top right. B: The runoff of Pildappa Rock is diverted along the base of the hill by low walls, which channel water into drains and thence into the storage tank. C: Tank at Kolballa Hill, north-western Eyre Peninsula, South Australia. Kolballa Station was one of the first pastoral stations in the interior of the northern Peninsula and was based on water derived from the granite hill.

On a global scale, these granite upland-based conservation schemes are only minor but they are locally significant. Furthermore any saving of water, especially potable water, is admirable for water always has been, and remains, a vital commodity. It is the most precious of all our mineral resources and will become even more important. It has been estimated that by 2050 AD, the world's population will be of the order of 10 billion. Many will be short of water, for though there are about 14 $x10^{23}$ (1400 billion billion) litres of water on Earth, 97.5% of this is seawater and only 0.8% is potable and accessible. At the present time, every person on Earth uses on average one million litres every year, most of it for producing food or in manufacturing (*sensu lato*), but also, in the so-called developed world, for such labour-saving devices as dishwashers, washing machines and automatic car washers. There is still enough, on average, though some areas like central Asia, the Levant, and much of Africa, are already chronically short of water. But, with water use having tripled over the past half century, and doubling every 20 years, this will not be true for much longer. In those areas that are either overpopulated, or like most of Australia already short of water, there will be problems. Thus though water gathered and stored from granite outcrops may not loom large in the global water supply equation, every little source helps, and potential sources of water must not be recklessly destroyed. Even minor catchments like the granite bornhardts of the Wheatbelt of Western Australia and of northern Eyre Peninsula may become even more useful than they are and have been. Conservation must be encouraged and future needs borne in mind.

Recreation and tourism

Many granite outcrops stand high in the local topography and offer good views. Some have been sculptured into elegant, odd or just plain interesting shapes. Tafoni, with the opportunities they offer for games such as hide-and-seek, are irresistible to children. For these reasons, many granite hills are used for recreational purposes, either casually or in an organised fashion. Thus, many hills are used locally and informally for picnics, walks, runs and climbs; and though unspectacular this function cannot be overvalued for these sites provide invaluable space, interest and relaxation for many families and small communities.

On the other hand, many granite hills are tourist attractions, at various scales. Some provide excellent facilities and information, whereas others are good but low key. Hyden Rock generally, but Wave Rock in particular, is the prime example of intensive tourist activity (Twidale & Bourne 2000b). Facilities, including accommodation and food outlets, are excellent, and considerable trouble has been taken to encourage not only the casual camera-toting visitor but also those, increasing in number, who look for or are attracted by accurate information about what they are seeing and are willing to spend time exploring the area to improve their understanding. The information offerings are varied and include not only features of geological, and botanical interest but also something of the history and life of the district.

Murphy Haystacks, on north-western Eyre Peninsula, is an example of a low-key tourist site. These 'Haystacks' consist of granite pillars with flared sidewalls (Twidale & Campbell 1984; Fig 5) standing in a row on the crest of a hill just to the west of the main Port Lincoln-Streaky Bay road. They stand on what was Pat Murphy's property and it is said that the coachmen travelling the road would point out these haystack-shaped rocks to their passengers. They are unusual forms, with many minor features of interest, and to some eyes are aesthetically pleasing and reminiscent of some of Henry Moore's works. But they attract only a few visitors. Nevertheless, the notes displayed alongside the entry path simply, clearly and succinctly relate how the features originated. There is no shop selling drinks or souvenirs, and no

Figure 5. Part of Murphy Haystacks, a group of granite pillars between Streaky Bay and Port Kenny, north-western Eyre Peninsula.

charge for entry - just an honour box for donations for the upkeep of the facility.

Other sites are not so praiseworthy. Some authorities persist in propagating false information in order to sound the most (largest or smallest, highest or lowest, or whatever). For example, in addition to introducing conceptual errors, it is still claimed on official notices that Mt Wudinna (properly, Wudinna Hill) on north-western Eyre Peninsula is a monolith second in size only to Ayers Rock, whereas not only are there many higher and more extensive hills in various parts of Western Australia and in central Australia (*e.g.* The Granites, western Northern Territory, and the Everard Ranges in north-western South Australia), but Carappee Hill, only 120 km to the south-east of Wudinna is much higher and more extensive than Wudinna Hill. This error, and others which would be hilarious were they not so grossly and obviously inaccurate, is perpetrated and perpetuated despite accurate information having been provided to the body responsible for the notices. (A case of a good story overriding truth, a tendency which has shown up elsewhere). Moreover, some of the concepts mentioned are distorted or incorrect, and in some instances the presentation is ungrammatical. Considered altogether, such misinformation is worse than no information being offered.

Edutourism is another area of future development. Various restrictions concerning safety and entry to properties (and related legal obstacles) have made group education, whether at school, university or club level, difficult, and this together with the growth of such institutions as U3A (University of the Third Age, intended for adults with no formal or paper educational qualifications) will produce a growing demand for organised educational tours at specific, especially suitable, sites.

Conservation and management

Various demographic and social factors suggest that (eco)tourism and edutourism are industries of the future. If advantage is to be taken of this trend, then the granite outcrops must be prepared not only for use but also for preservation. Not only must accurate information be presented by way of literature and signage, but sites of special significance must be protected, as must vulnerable areas of the uplands. For example, false claims as to the local feature being the largest or smallest, oldest or youngest, have no place in advertisements; delicate features such as siliceous speleothems call for special protection, possibly by not being advertised; and patches of soil which are home to various plants need to be protected against trampling feet.

Building adjacent to granite hills ought to be controlled and again be subject to inquiry and permission from an impartial body. Outcrops destined for major tourist development need protection from humans. There is a choice of allowing visitors to wander at will, or to channel them into prescribed walks, although this dictates that some vulnerable areas may be trampled. In such areas, soil ought to be protected by slabs (of local rock), fencing and raised wooden decking. Even bare granite rock can be worn away in time and needs protection (in Galicia, north-western Spain, there are straight parallel gutters some 10-25 cm deep eroded in fresh granite due to the repeated passage of cart wheels, presumably iron shod). Visitors ought not to use footwear with metal studs or plates; rubber or plastic soles are preferable.

Tidiness ought to be encouraged (and time and money saved) by providing discreetly designed and placed rubbish containers. In addition it will be necessary to organise regular clean-ups to take account of the careless visitor.

Discussion

Nature and human interest, both aesthetic and scientific, have determined those outcrops that are of tourist, recreational or educational value and existing regulations and public opinion will presumably ensure that they will not be ravaged by quarrying in the foreseeable future. Similar but lesser concerns will limit the use made of such sites for water conservation; although such schemes need not be ugly and may indeed enhance the local landscape, for water (a reservoir) almost always adds to the attractiveness of scenery although diversion walls, fences and associated debris do not. One difficulty is that sites that are pleasant and interesting and locally useful for recreation, but carry or display nothing unique, may be endangered. Another is that significant features may not be recognised or appreciated at this time.

To help overcome these difficulties, it is suggested first that all major outcrops, and any others known to have features of interest, and any that are proposed for quarrying, ought to be surveyed, described and photographed (geology, landforms, flora, fauna, water potential and needs, historical significance). The survey techniques developed by the former CSIRO Land Research groups (*e.g.* Christian 1952) and classification and evaluation criteria evolved by various American agencies could be utilised (for a theoretical treatment of perceptions of landscape see *e.g.* Tuan 1974). The purpose would be first to record all that can be about the hills or outcrops, in case they eventually are destroyed, and second to form the basis of a register of outcrops. They could be then assessed and assigned a category according to perceived importance, with reasons given. Granite landforms are quite well understood (*e.g.* Twidale 1982a, Campbell 1997; Vidal Romani & Twidale 1998) but not all is known about them and there remain many debatable points. But whether understood or not, total morphology ought to be recorded. Possible utilisation could also be indicated in terms of such an evaluation.

Such a survey would allow the identification of sites that are of value for conservation or as sources of biological renewal, or that are of value for teaching purposes or which clearly demonstrate points of scientific argument and debate. Thus, Wave Rock is a superb example of a flared slope, and Yarwondutta Rock near Minnipa on north-western Eyre Peninsula is of scientific importance because of the spendid exposure of a concave weathering front which was naturally subterranean but which has been exposed by excavation in the interests of water conservation (Twidale 1962). In addition, the compact two metre exposure but complex regolithic profile exposed in a nearby quarry (Twidale 1986), and

Figure 6. The stepped north-western slope of Yarwondutta Rock, Minnipa, north-western Eyre Peninsula. South Australia.

its overall stepped morphology (Fig 6) carries clear implications for general theories of bornhardt and of landscape evolution (Twidale & Bourne 1975; Twidale 1982b).

Granitic "islands in the bush" are subject to competing claims. In order to evaluate these claims in terms of particular sites it is suggested that an overall review and evaluation of major granite hills be undertaken to form the basis of optimal utilisation and conservation.

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